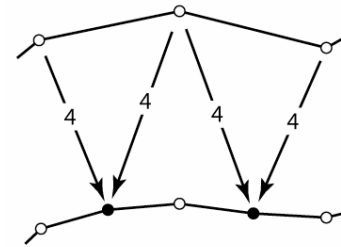


Subdivision Overview

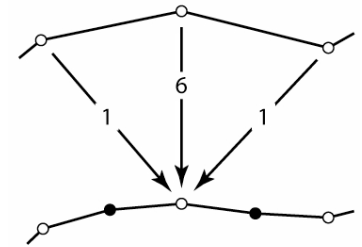
CS 462I Lecture I

Subdivision rules for curves

- New vertex positions are linear combinations of old positions



ODD



EVEN

Subdivision curves

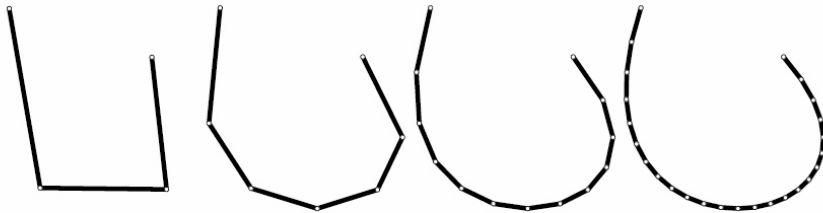


Figure 2.1: Example of subdivision for curves in the plane. On the left 4 points connected with straight line segments. To the right of it a refined version: 3 new points have been inserted “inbetween” the old points and again a piecewise linear curve connecting them is drawn. After two more steps of subdivision the curve starts to become rather smooth.

[Schröder & Zorin SIGGRAPH 2000 course 23]

Subdivision surfaces

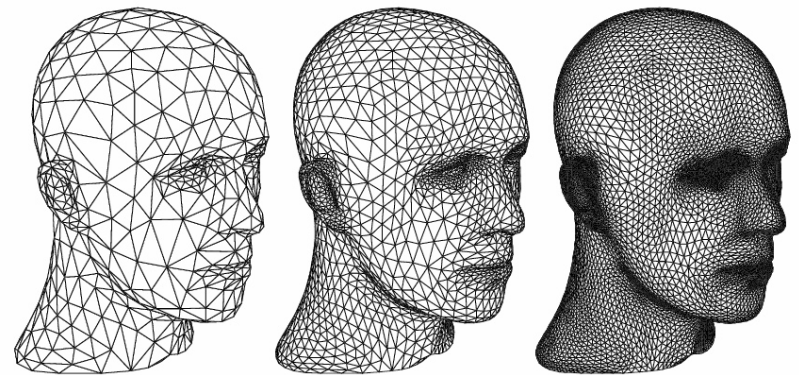


Figure 2.2: Example of subdivision for a surface, showing 3 successive levels of refinement. On the left an initial triangular mesh approximating the surface. Each triangle is split into 4 according to a particular subdivision rule (middle). On the right the mesh is subdivided in this fashion once again.

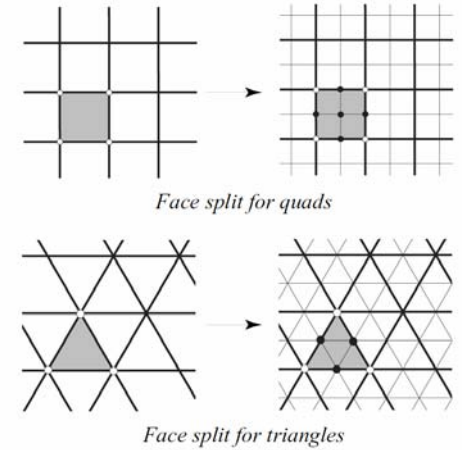
[Schröder & Zorin SIGGRAPH 2000 course 23]

Generalizing from curves to surfaces

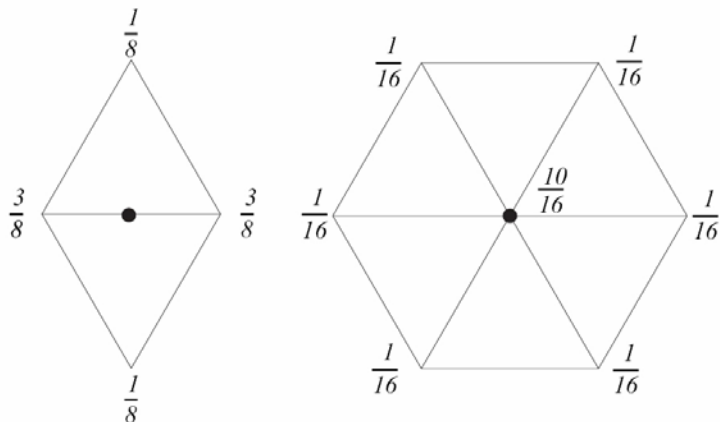
- Two parts to subdivision process
- Subdividing the mesh (computing new topology)
 - For curves: replace every segment with two segments
 - For surfaces: replace every face with some new faces
- Positioning the vertices (computing new geometry)
 - For curves: two rules (one for *odd* vertices, one for *even*)
 - New vertex's position is a weighted average of positions of old vertices that are nearby along the sequence
 - For surfaces: two kinds of rules (still called *odd* and *even*)
 - New vertex's position is a weighted average of positions of old vertices that are nearby in the mesh

Subdivision of meshes

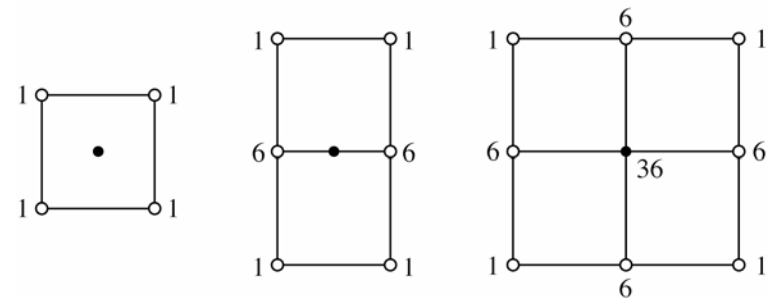
- Quadrilaterals
 - Catmull-Clark 1978
- Triangles
 - Loop 1987



Loop regular rules

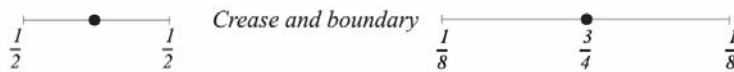


Catmull-Clark regular rules



Creases

- With splines, make creases by turning off continuity constraints
- With subdivision surfaces, make creases by marking edges “sharp”
 - use different rules for vertices with sharp edges
 - these rules produce B-splines that depend only on vertices along crease



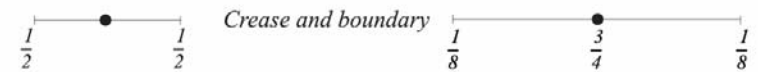
a. Masks for odd vertices

b. Masks for even vertices

[Schröder & Zorin SIGGRAPH 2000 course 23]

Boundaries

- At boundaries the masks do not work
 - mesh is not manifold; edges do not have two triangles
- Solution: same as crease
 - shape of boundary is controlled only by vertices along boundary



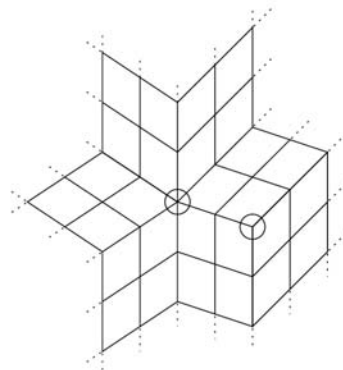
a. Masks for odd vertices

b. Masks for even vertices

[Schröder & Zorin SIGGRAPH 2000 course 23]

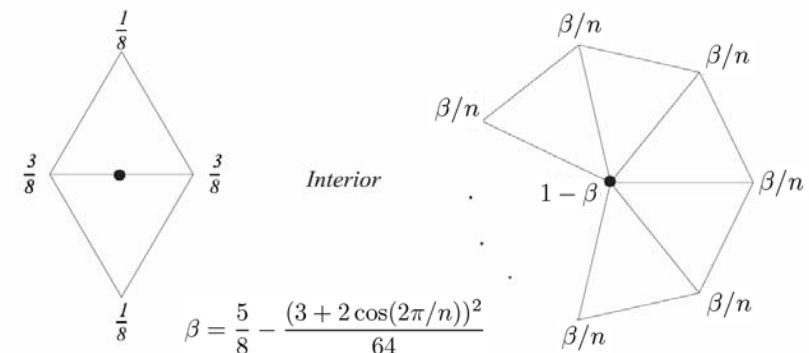
Extraordinary vertices

- Vertices that don't have the “standard” valence
- Unavoidable for most topologies
- Difference from splines
 - treatment of extraordinary vertices is really the only way subdivision surfaces are different from spline patches



[Schröder & Zorin SIGGRAPH 2000 course 23]

Full Loop rules (triangle mesh)



a. Masks for odd vertices

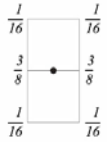
b. Masks for even vertices

[Schröder & Zorin SIGGRAPH 2000 course 23]

Full Catmull-Clark rules (quad mesh)



Mask for a face vertex

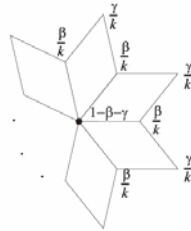


Mask for an edge vertex



Mask for a boundary odd vertex

a. Masks for odd vertices



Interior

$$\beta = 3/2k; \gamma = 1/4k$$

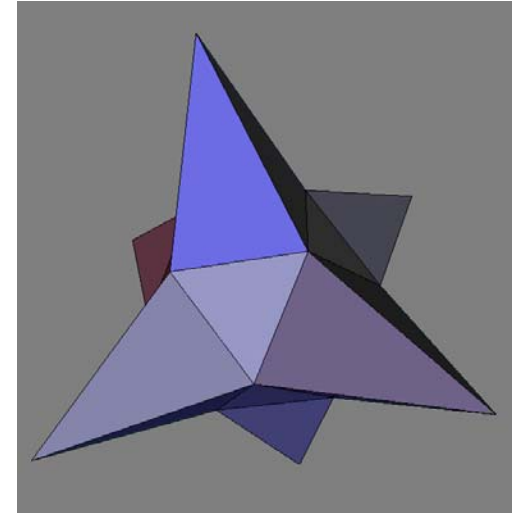


Crease and boundary

b. Mask for even vertices

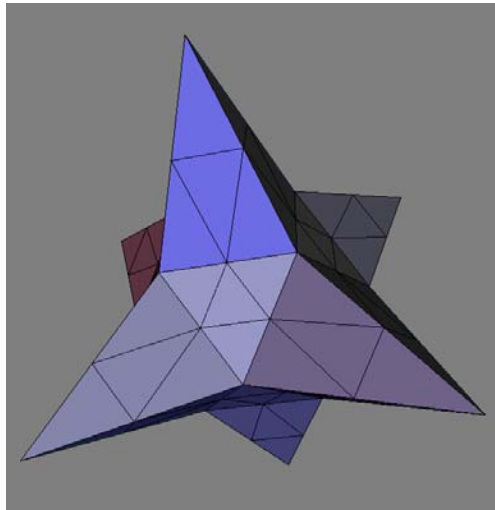
[Schröder & Zorin SIGGRAPH 2000 course 23]

Loop Subdivision Example



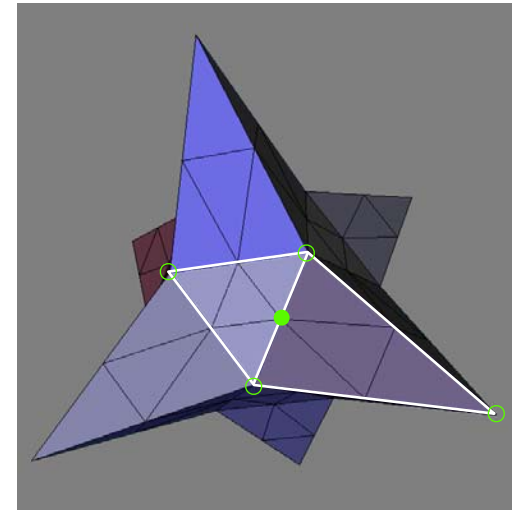
control polyhedron

Loop Subdivision Example



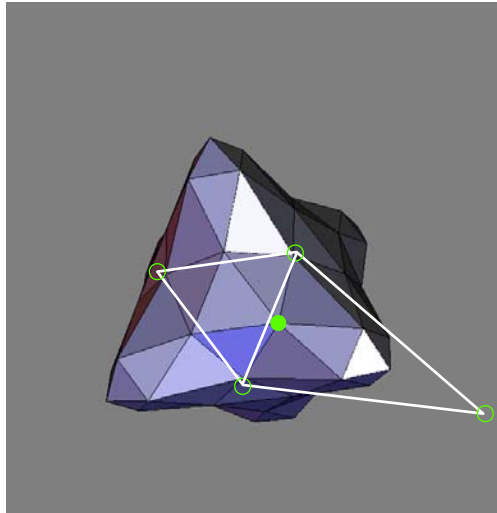
refined control polyhedron

Loop Subdivision Example



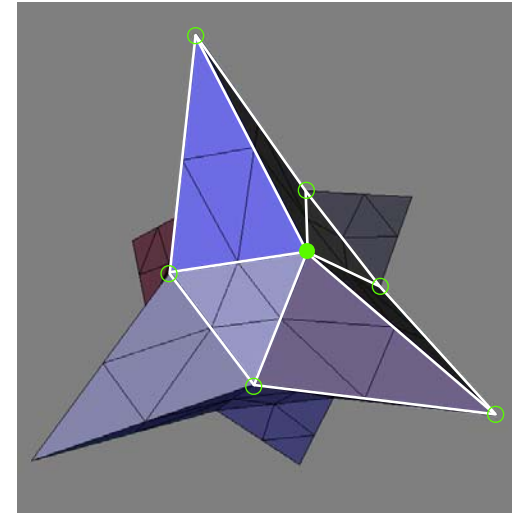
odd subdivision mask

Loop Subdivision Example



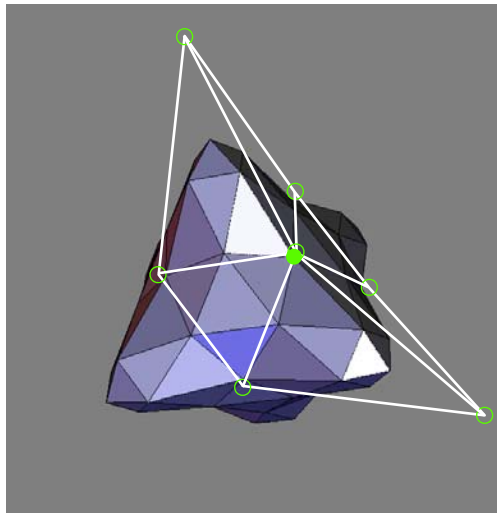
subdivision level 1

Loop Subdivision Example



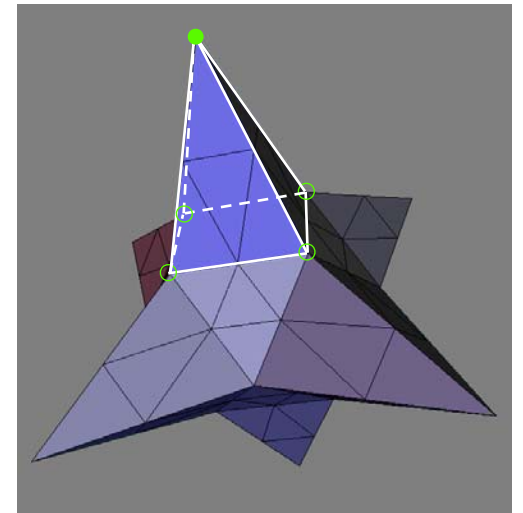
even
subdivision mask
(ordinary vertex)

Loop Subdivision Example



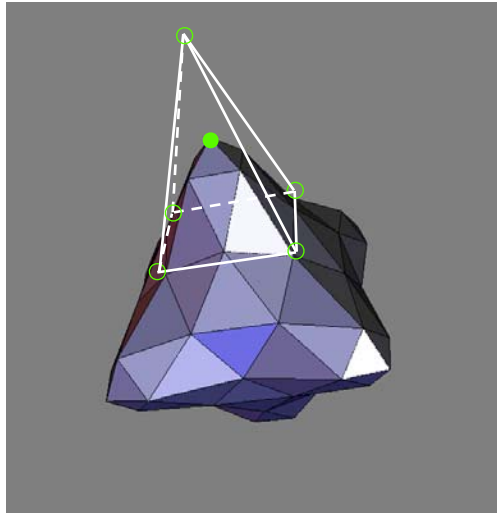
subdivision level 1

Loop Subdivision Example



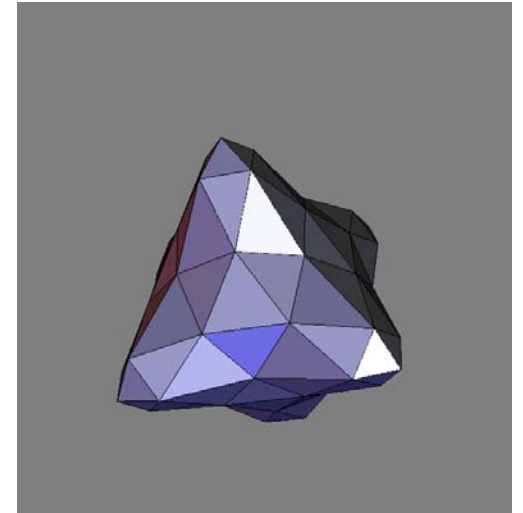
even
subdivision mask
(extraordinary vertex)

Loop Subdivision Example



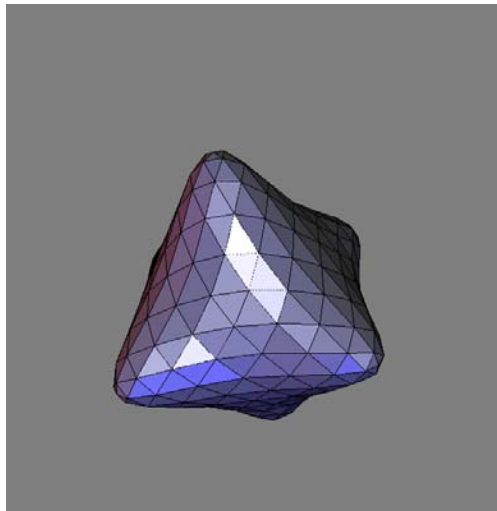
subdivision level 1

Loop Subdivision Example



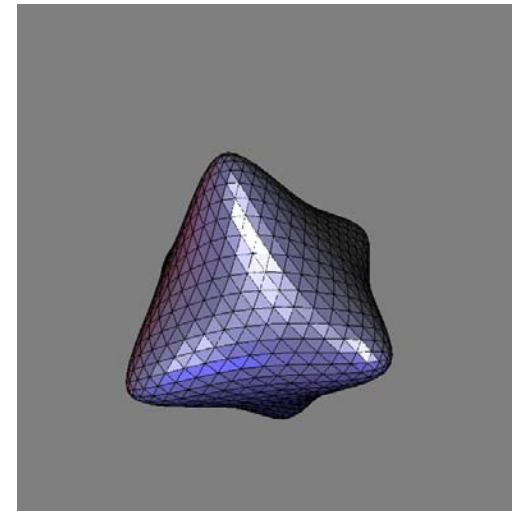
subdivision level 1

Loop Subdivision Example



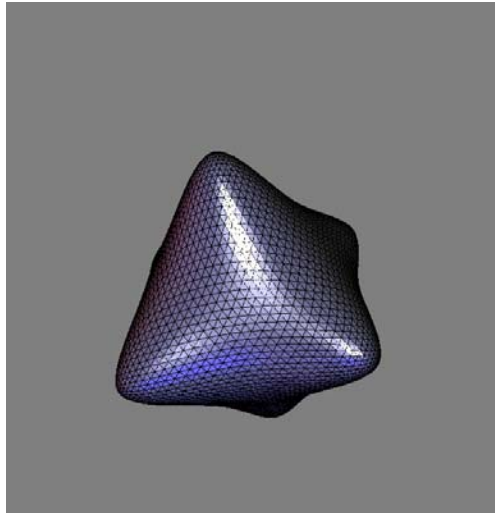
subdivision level 2

Loop Subdivision Example



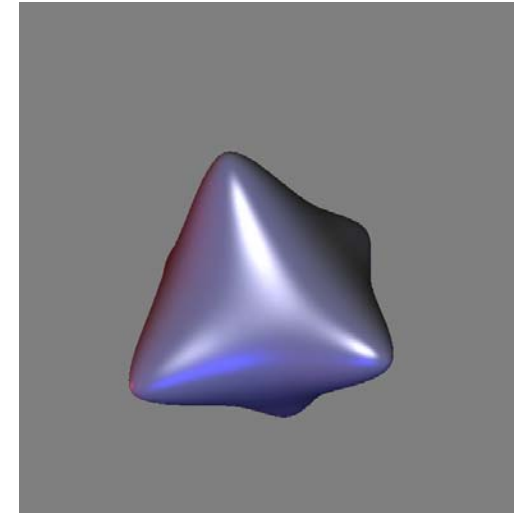
subdivision level 3

Loop Subdivision Example



subdivision level 4

Loop Subdivision Example

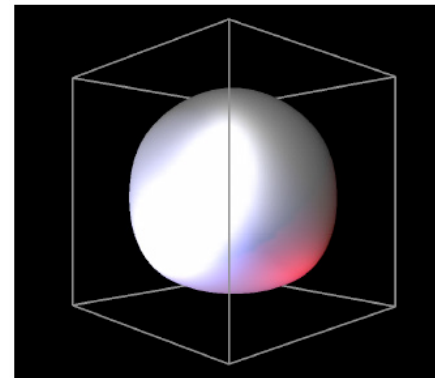


limit surface

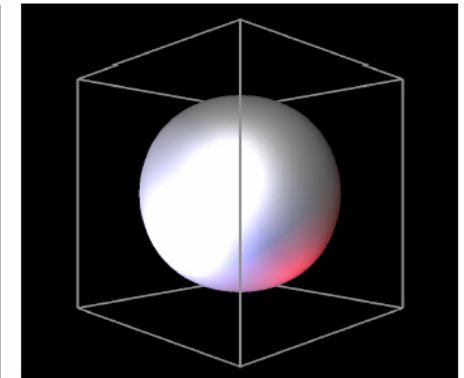
Relationship to splines

- In regular regions, behavior is identical
- At extraordinary vertices, achieve C^1
 - near extraordinary, different from splines
- Linear everywhere
 - mapping from parameter space to 3D is a linear combination of the control points
 - “emergent” basis functions per control point
 - match the splines in regular regions
 - “custom” basis functions around extraordinary vertices

Loop vs. Catmull-Clark

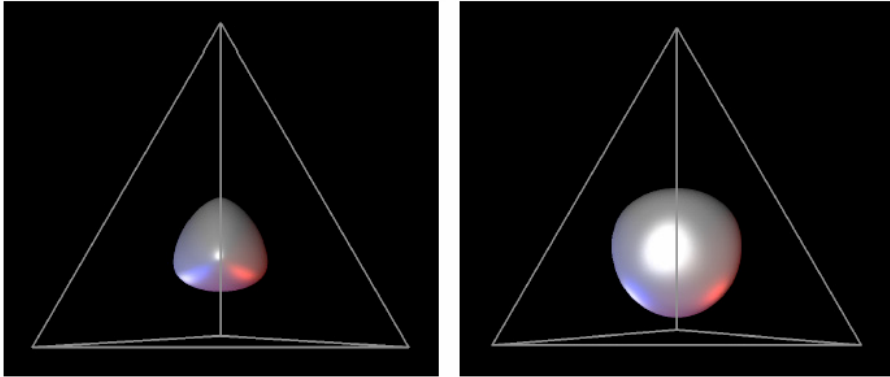


Loop



Catmull-Clark

Loop vs. Catmull-Clark

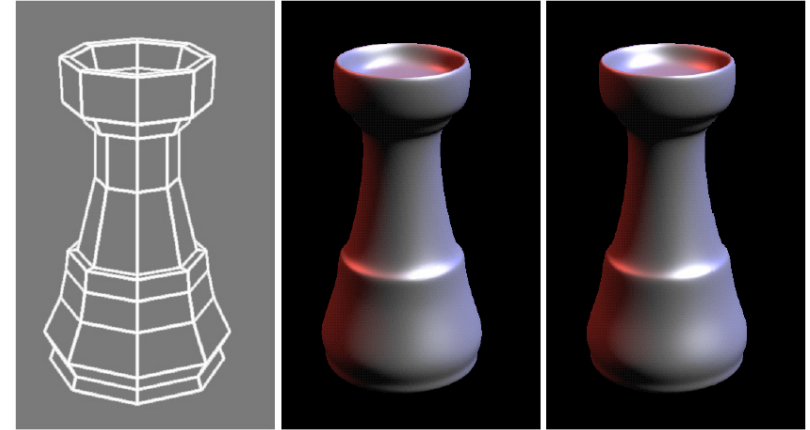


Loop

Catmull-Clark

[Schröder & Zorin SIGGRAPH 2000 course 23]

Loop vs. Catmull-Clark

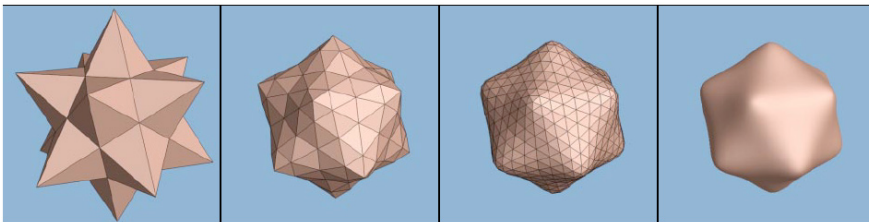


Loop
(after splitting faces)

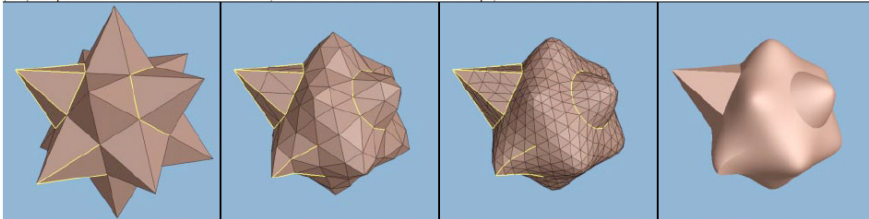
Catmull-Clark

[Schröder & Zorin SIGGRAPH 2000 course 23]

Loop with creases



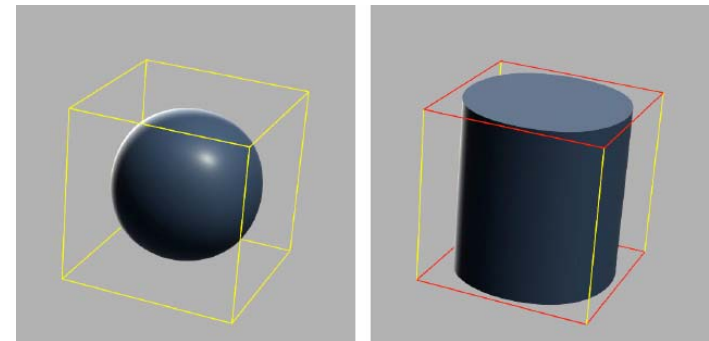
(a-d) Loop's subdivision scheme: control mesh, meshes after 1 and 2 subdivision steps, and smooth limit surface



(e-h) Our piecewise smooth subdivision scheme: tagged control mesh, meshes after 1 and 2 subdivision steps, and piecewise smooth limit surface

[Hugues Hoppe]

Catmull-Clark with creases



[DeRose et al. SIGGRAPH 1998]

Geri's Game

- Pixar short film to test subdivision in production
 - Catmull-Clark (quad mesh) surfaces
 - complex geometry
 - extensive use of creases
 - subdivision surfaces to support cloth dynamics



[DeRose et al. SIGGRAPH 1998]